BASIS OF DESIGN SUMMARY MEMO
SOUTH PRAIRIE CREEK CHANNEL RESTORATION

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August 14, 2015

INTRODUCTION

Natural Systems Design, Inc. (NSD) has prepared this Basis of Design Summary Memo to summarize key elements of field work, site assessment and analysis which has formed the foundation of the proposed restoration design for South Prairie Creek, which will entail the following elements:

- Installation of instream structures in the existing channel
- Construction of an anabranching channel network on the former floodplain
- Revegetation of the restored floodplain / channel complex

ARCHAELOGY

A full archaeological analysis of the site was performed in 2013 and found no evidence of permanent settlement, but that it was a hunting area. A fire ring was found on the far east (upstream) end of the project area on high ground situated near the 100-year flood elevation. Artifacts found on the site consist of small arrow points which would have been used for bird hunting. Areas with artifacts were exluded from all proposed excavation activities.

HYDROLOGY AND HYDRAULICS

Flow data for SouthPrairie Creek was collected from USGS website for USGS Gage Station 12095000, "South Prairie Creek". A log Pearson Type III distribution analysis was performed to develop a probability analysis of flow recurrence, key elements of which are summarized below.

Recurrence Interval (yrs)	Q (cfs)
1.01	830
1.1	1,480
1.5	2,940
2	2,940
5	4,540
10	5,660
25	7,130
50	8,250
100	9,400

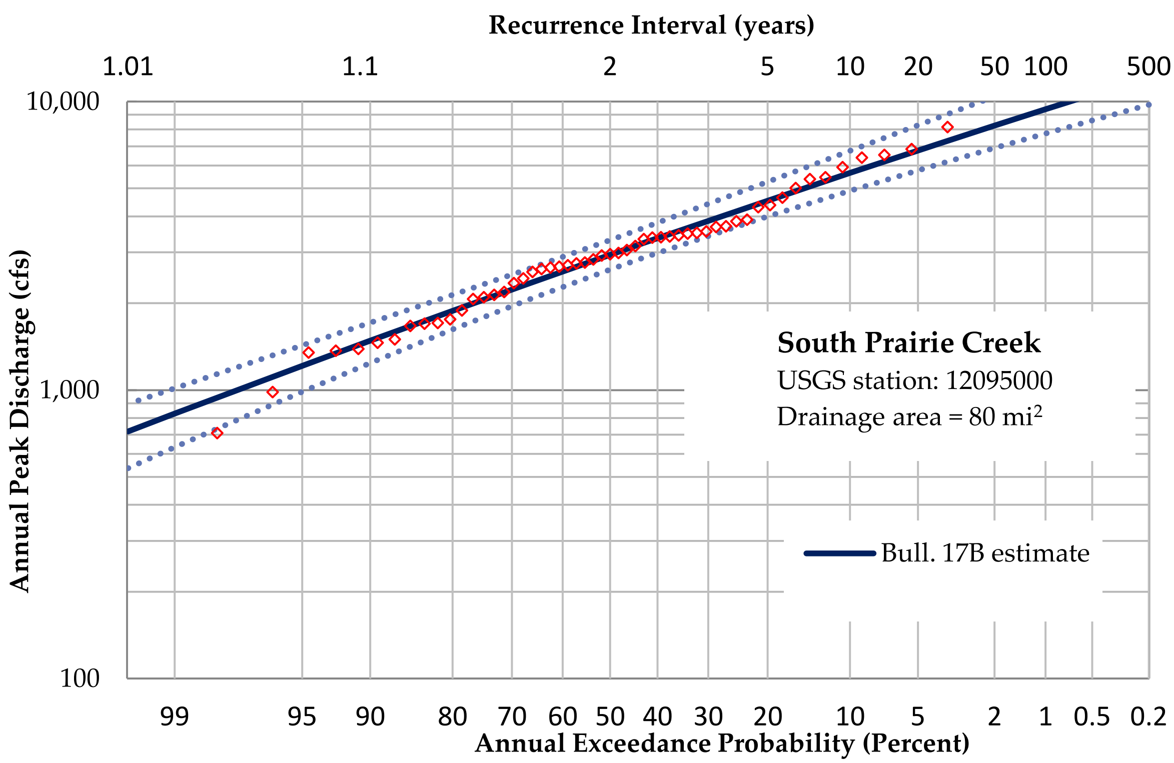

Figure 1. Plot of peak discharge versus recurrence interval for South Prairie Creek.

The 1.1 year recurrence interval flow of 1,480 cfs was selected as the formative discharge (bankfull flow) as respresentative for Western Washington streams based on "Bankfull Discharge Recurrence Intervals and Regional Hydraulic Geometry Relationships: Patterns in the Pacific Northwest, USA.", Castro and Jackson, 2007.

Hydraulic analysis was performed of the existing channel using the hydrodynamic model Riverflo 2D. Model results show that the 1.1-year recurrence peak flow (Q1.1) remains entirely confined within the existing channel even though undisturbed alluvial channels in Western Washington tend to crest their banks at peak flows with a recurrence of 1.1 (Castro and Jackson 2007). These results are consistent with geomorphic evidence that the creek bed has incised 4-5 ft below the bed of relic channels in the floodplain. During a Q1.1 flow the existing channel has velocities of 6-10 fps which are in the upper range of sustained swimming speeds of resident and anadromous fish. During a Q100 flow the majority of the existing channel experiences velocities equal or greater than 10 fps. It appears that the historic channel had significantly lower velocities than the existing channel based on review of relic channels and floodplain characteristics. The relic channels had higher sinuosity (K_relic >1.5, K_existing =1.1), smaller bed material grain size (D50_relic = 50 mm, D50_existing = 250 mm), and lower gradient (S_relic approx. 0.4%, S_existing approx. 0.8%). Model simulations indicate that the proposed restoration design will reduce the Q1.1 velocities to 2-4 fps in the proposed channels and 3-7 fps in the existing channel; this would be consistent with that likely found in historic channel conditions. Due to the simplified nature of the existing channel (near-vertical banks, predominantly plane bed conditions through the reach), there is little in-channel or off-channel refuge available for fish. The is almost no spawning within the project area due to the coarse substrate and high velocities of the existing channel. Hydraulic analysis shows that even at the 100-year flow event, only shallow flows of 0.1 -0.5 ft occur across the project area. Agricultural practices of repeated plowing over time have smoothed the landscape and disconnected low areas of the floodplain on the downstream (west) end of the project area. Model results show how these changes create ponding on the floodplain that could strand fish. Pierce County and Tacoma Water staff have observed fish stranding on the floodplain after major storm events.

GEOMORPHOLOGY

A geomorphologic analysis of the site was performed by NSD in 2013, including review of prior geologic and channel migration studies, review of LIDAR topographic data, on-site excavations to review soil stratigratphy and on-site identification of existing and relic channel geometry and substrate. In summary, following the Oceola mudflow, the creek formed its modern valley which was characterized by a forested floodplain and anabranching channel network. It is believed that historic channel straightening, deforestation and removal of wood from the stream channel concurrent with agricultural development and channel confinement at downstream bridges increased stream power. This triggered channel downcutting through the creek's alluvial deposits of sand and gravel down to the pre-historic cobble-boulder alluvium deposited by the White River prior to the Oceola mudflow. This coarse material formed an effective armor on the stream bed that has limited further downcutting. The current channel elevation has remained relatively stable over recent history as evidenced by review of stream cross-sections compiled historically and re-occupied with new site survey in 2014. The current channel substrate through the majority of the reach ranges from coarse cobble (6"-12") to mid-size boulders (2' –3' diameter). Current channel alignment has been stable over the past few decades due to rock revetments placed along banks that would have otherwise been subject to erosion. In one location in the upper reach, several mature cottonwoods have fallen into the creek along the south edge, directing flow to the north into the right bank. During the 2009 flood this site is where erosion of the right bank increased the width of the channel which in-turn reduced flow depths and bed shear so that gravels (2"-6") eroded from the bank and those coming from upstream were retained where the channel had widened. The slope of the existing channel is approximately 0.8% with individual boulder riffles over 4%. Review of vertical cut slopes along the upstream north side of the existing channel show that the historic undisturbed channel had a substrate of 1" – 6" gravel with channel bank heights of 2' – 3' below the abandoned floodplain. Site review of relic channels evident along portions of the project area have the same size gravel present and visible within the channel bottom at the similar elevation as isevident within the cut slopes. These gravel deposits were found in various locations throughout the project area, indicatingthe historic channel thalweg was several feet above the level of the current channel. A sand layer is present above the gravel layer and ranges from 1' – 6' in depth across the site, evidence that the creek frequently flooded and had much lower velociites than currently occurring at the site.

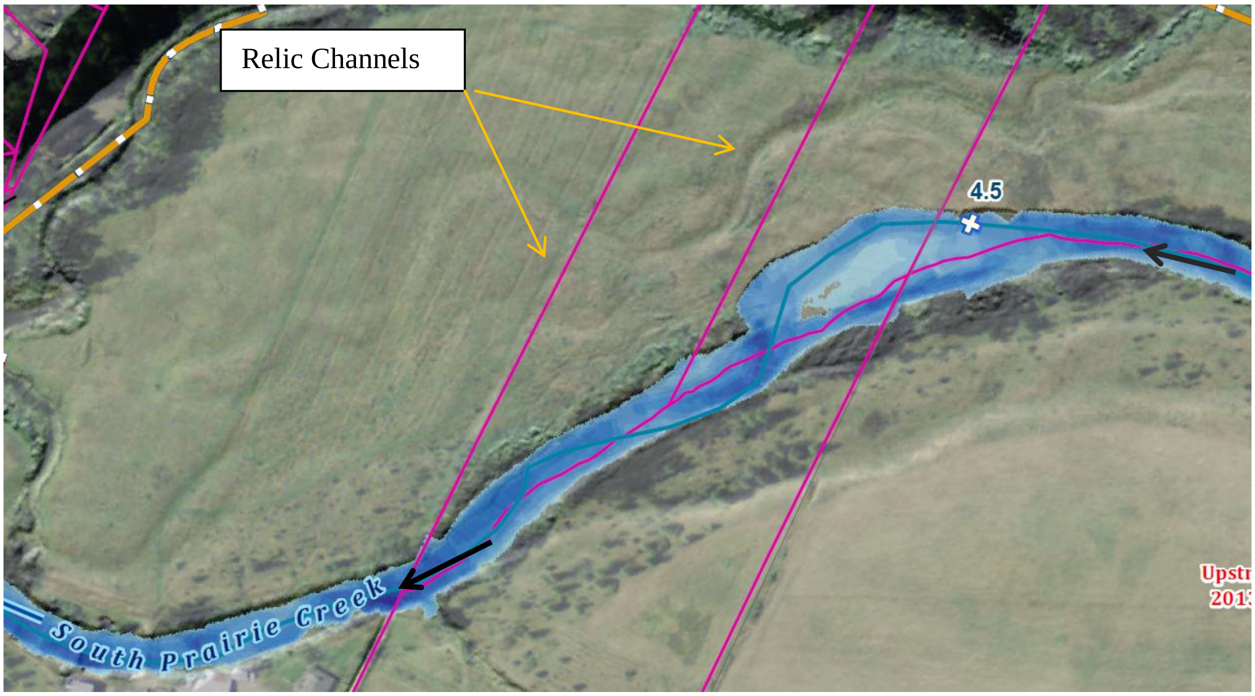

Figure 2. Hillshade image of existing site at Q1.1 showing relic channels along north abandoned floodplain area

Groundwater is present throughout the site and was observed several feet from the ground surface in the field work performed in the winter of 2013. Hillslope runoff from the north side of the site are a significant contributor, as evidenced by a surface water expressed within a wall-based ditch flowing full along the north edge of the site. A groundwater collection and storage system located at the northwest property boundary and operated by Tacoma Water collects a portion of the groundwater in an infiltration gallery and pumps it upslope to residential customers located on the hilltop. Monitoring tubes have been installed in transects through the project site with transducers to monitor groundwater elevations through time, the data from which will be used to inform final design of the stream channel and vegetation.

A multi-thread (anabranching) channel design was selelected for this site based on review of site topography and analysis of channel formed as a function of formative discharge, channel slope and grain size (Eaton et al. 2010). The same formative discharge (1,480 cfs) applies to both the existing and historic channels, so using the different median grain sizes (D50) and channel slopes, we can plot the two conditions to predict a braided, anabranching or single thread channel form (Eaton et al. 2010). The existing channel (D50=250mm, slope=0.008) is shown to lie within the range associated with single thread channels, while the historic channel (D50=50 mm, slope=0.0035) plots in the anabranching domain (Figure 1). This is consistent with the topographic and sedimentologic evidence of relic anabranching channels on the floodplain and the recent history of confinement and incision of the existing channel.

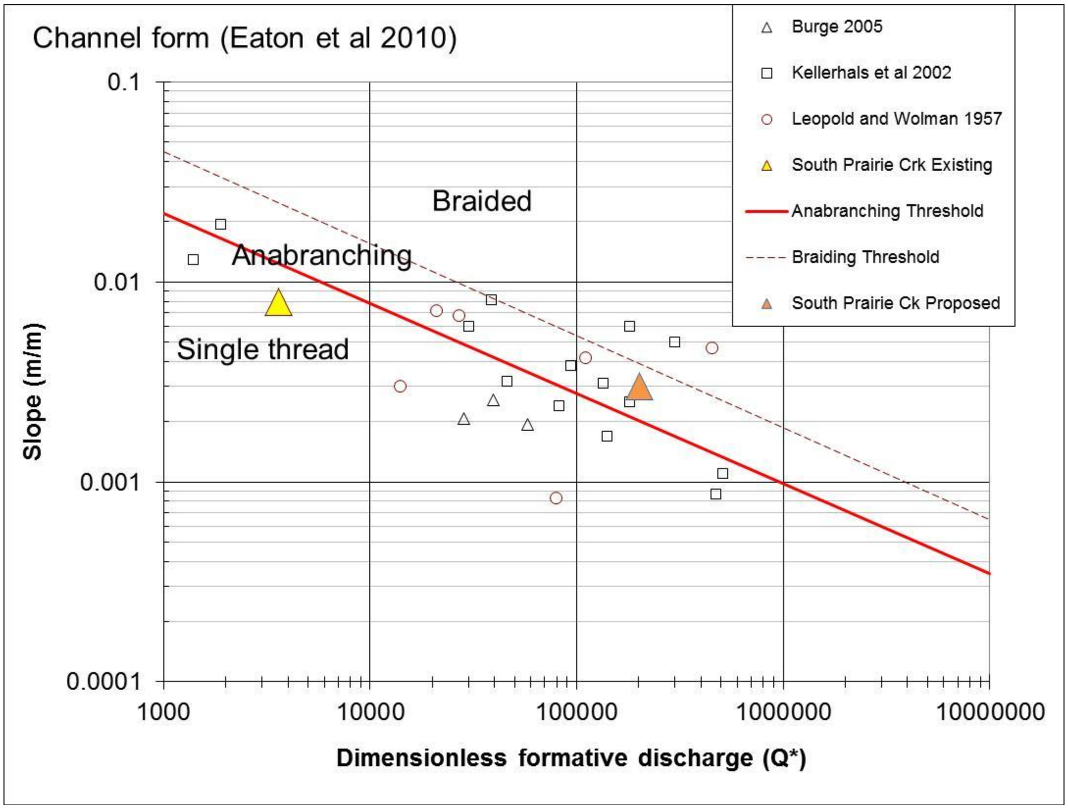

Figure 3. Predicted form of the existing and historic (proposed) channels of South Prairie Creek within the project reach based on slope and dimensionless formative discharge, Q*. Q* is a function of peak flow with 1.1 yr recurrence and median grain size (D50).

ALTERNATIVES ANALYSIS

Three alternatives were identified and evaluated to allow re-establishment of an anabranching channel network within the project area.

Alternative 1. This would consist of installing instream structures built from large wood and boulders in the existing channel to increase channel roughness, increase instream hydraulic complexity and raise water surface levels sufficiently to create lateral and vertical hydraulic connectivity to adjacent floodplain areas. The backwater effect of the structures would cause deposition of incoming bedload in the existing channel, decrease instream sediment size and reduce in-stream velocities. Little or no construction activity would occur outside of the existing channel. The flows over the floodplain would be expected, over time, to cut ephemeral side channels.

Alternative 2. This alternative would include the instream structures in the existing channel as with Alternative 1, and would also cut inlet channels at upstream locations to reduce the vertical height of the instream structures, achieve floodplain connectivity at lower flood levels and meet FEMA and County requirements to prevent upstream backwater effects from increasing flood risk to offsite properties. Log structures would be installed in the north floodplain to increase floodplain roughness which would reduce floodplain velocities and encourage scour which could speed formation of ephemeral (and potentially perennially-flowing) side channels. The log structures would reduce risk of high flood flows causing damage to the downstream Spring Creek project.

Alternative 3. This alternative is would include the instream structures in the existing channel as with Alternative 2, and would also include excavation of a low-flow channel intended to be perennially-flowing, as well as flood channels to connect above the Q1.1 flood level. Similar to Alternative 2, the cut channels would relieve upstream flood levels sufficiently to meet County and FEMA requirements. Log structures would be installed in the floodplain to increase floodplain roughness and provide fixed points along the new side channel to scour out pools and provide areas of low-velocity refuge in the lee of the structures during flood flows. The material cut from the channel would be placed onsite to create upland habitat and be located on the north and northwest side of the site to reduce risk of high flood flows causing damage to the downstream Spring Creek project.

Each alternative is listed below with key decision elements of pros and cons associated with each; the alternatives and evaluation matrix are attached to this memo. This is a very brief summary of the more complete analysis which was evaluated by the project team and stakeholders (NSD 2013).

Alternative	Pro	Con
1. Instream structures in existing channel	Lower cost	Likely to cause upstream flooding in excess of allowable FEMA limits Lower habitat value Likely to cause sheet flow depths shallow enough to increase fish stranding risk on floodplain Unclear how long it would take for ephemeral side

		channels to emerge May increase risk of flood damage to downstream Spring Creek restoration project.
2. Instream structures in existing channel and “starter” inlet channels and floodplain roughness	Medium cost Reduces upstream flood levels to within FEMA limits Would over time likely cut ephemeral flood channels	Unlikely to produce perennial side-channel flow Unpredictable locations for channel network on the floodplain due to floodplain modifications from agriculture Potential to increase fish stranding risk on floodplain surfaces along lower half of site
3. Instream structures in existing channel and constructed channel network	Ensures upstream floodlevels maintained within FEMA limits Highest habitat value for refuge, rearing, spawning and poses least risk of fish stranding Establishes perennial flow in channel network Work can be sequenced to minimize flow bypass costs	Higher cost

After discussions with the project stakeholders, Alternative 3 was selected. Though it had the higher cost, it provided the most habitat enhancement benefit for off-channel refuge, as well as spawning and rearing habitat. The hydraulic response of this alternative was preliminarily analysed using Riverflo 2D and was found to provide perennial flow in the existing channel and the main side channel thread for base flow and bankfull flow, as well as meet the requirement of not raising 100-year flood levels upstream of the project. Also, the majority of the work can be completed in dry conditions by sequencing the project such that the side channel creation would be created first, then the flow would be routed into the side channel for construction of elements within the existing channel.

During design development, several elements were modified from Alternative 3 to reduce project costs and to allow natural channel development processes to form the floodplain channel. Excavation was reduced to the minimum amount needed to ensure that no flood elevation rise is experienced at the upstream end of the project. Key changes include:

- Side channel alignment directly follows the historic relic channel alignment.
- Reduction in cross-section of side channel
- Elimination of overbank flood channels on the north floodplain
- Elimination of large post-supported ELJs on the floodplain
- Elimination of overbank flood channel on the south floodplain

DESIGN ELEMENTS OF PREFERRED ALTERNATIVE

Primary design elements developed to date are listed below with a brief discussion on each. The drawings illustrate each design element.

Instream structures in the existing channel. In order to minimize the cut volumes associated with re-establishing an anabranching channel network, instream structures are proposed in the existing channel to raise the water surface elevations within the channel as much as four feet. To maximize habitat value, three of the structures will be constructed primarily of large wood and stabilized with streambed boulders (ELJ type 2). The most downstream structure will be comprised of a mix of wood and boulders due to the steep vertical banks in this area and the importance of ensuring a reliable hydraulic connectivity downstream of the confluence of the existing and new channels. Loss of grade control at this location could trigger headcutting up the new channel network which would disconnect the channels from the adjacent floodplain.

Connecting relic side channel. A single-thread channel following the relic channel aligment will be created on the floodplain, cut down sufficiently to hydraulically connect with the raised water surface in the mainstem channel. Total cross-section is minimized to just that which allows continuous connectivey a the 1.1 year flow and sufficient drainage to ensure no rise at the upstream end of the project at 100-year flow. All cut materials will be hauled to the south side of the project area and placed on the site of current farm buildings (to be demolished prior to construction). The channel elevations were compared to the groundwater monitoring data and it was determined that it is very likely that groundwater may contribute to flows in the proposed channel and/or be hydraulically connected in the pools during a significant portion of the year. The channel elevation was set as high as possible, such that flows greater than Q1.1 would spill out into the adjacent floodplain. This resulted in a typical slope of 0.5% through the majority of the channel length. The lower 500 ft of channel is at a slope of 1.35% to tie back into the mainstem thalweg.

The majority of the floodplain in the area of the new channel network is comprised of sand and small gravels. Due to a past farming and grazing practices, there is a nearly-complete lack of mature vegetation to provide scour resistance during flood flows. It is expected that this channel, cut into existing sand and gravels, will enlarge and deform over time in response to storm flows. Channel deformation may be significant, particularly if large storms occur within the first 5 years before vegetation gets established. As vegetation matures, lateral erosion rates and channel deformation will slow.

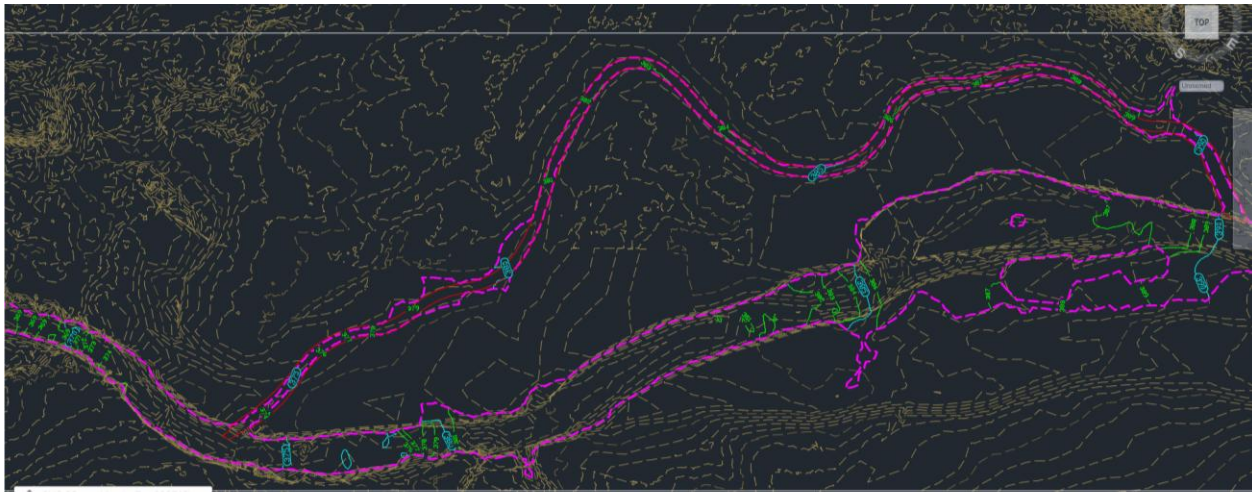

Figure 4. Predicted OHWM at Q1.1 (purple lines), showing continuous connectivity of the side channel and main channel.

<u>Large wood structures in and along the relic side channel</u>. The large wood structures are (ELJ type 3) intended to increase local scour to promote pool formation, increase overall site roughness to reduce flow velocities through the project area, focus flows into the relic side channel and reduce the risk of major avulsions through the area prior to vegetation establishment. A simple post-stabilized jam will be used, with posts long enough to penetrate below the historic White River bedload layer of boulders, approximately 6' under the existing floodplain surface. This is intended to ensure structure stability during the 100-year flow. The racking logs will provide significant intersticial complexity for aquatic and amphibious species. Roughness logs (ELJ type 1) will be installed in the downstream 500 ft of the side channel where the grade steepens to 1.35%. These are not intended to be weirs, but rather logs that extend below and above the grade to provide hydraulic roughness and instream complexity and reduce the risk of channel headcutting into the upstream segment of side channel that is at a flatter slope of 0.5%.

<u>Re-vegetation</u>. A re-vegetation plan is being developed for the project area by Pierce County Conservation District. Native plants will be specified to provide for soil stability, shade, cover and food production for the web of life anticipated to utilize the site including swimming, burrowingcrawling, walking, and flying species. Wetland plants will be installed in floodplain areas likely to develop hydric soil conditions and upland species will be specified for higher areas, specifically the cut earth mounds.